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SUPPLEMENTING ANTHRACITE WITH OTHER FUELS FOR HOME HEATING

BY

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SUPPLEMENTING ANTHRACITE WITH OTHER FUELS FOR HOME HEATING[1]

By W. T. Reid[2]

SUMMARY

A shortage of anthracite for home heating indicates the necessity of using other fuels for this purpose; low-volatile bituminous, or "soft" coal is the most feasible supplementary fuel, either burned alone or when mixed with anthracite.

Comparison of Bituminous Coal and Anthracite

Whereas anthracite is clean, burns without smoke, and requires little attention, bituminous coal is dusty, tends to burn with a smoky flame, and forms coke in the fire pot that must be broken up to maintain a continuous high output of heat. When properly fired, however, bituminous coal responds more quickly than anthracite to changes in damper settings and consequently can supply more heat in a short time. It is generally less expensive and usually contains less ash than anthracite.

Medium- and high-volatile bituminous coals are inherently smoke-producing and tend to deposit tar and soot in heating passages and chimneys. They break up easily when handled and require considerably more attention than anthracite but, generally speaking, can be substituted for anthracite in some burning equipment if proper care is taken in firing. Low-volatile bituminous coal can be burned smokelessly and with only a slight tendency to deposit tar or soot in the furnace or chimney. It, too, is easily broken in handling and may be dusty.

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Generally, low-volatile bituminous coal is the most readily obtained alternate for anthracite in New England and the Middle Atlantic States, and is considered the most suitable fuel for firing with or in place of anthracite when that fuel is difficult to obtain.

Equipment Best Suited for Burning Bituminous Coal as a Substitute for Anthracite

Equipment used for burning anthracite in domestic installations falls into two general classes - hand-fired and automatically fired. In general, hand-fired units will be most successful with substitute fuels. The approximate suitability of various types of equipment is indicated below:

A. Hand-fired:

1. Hot-air furnaces. - Best adapted to use of bituminous coal because of large combustion space; with correct firing, low-volatile bituminous coal can be burned alone with negligible smoke and soot formation.

2. Steam and hot water boilers. - If of the universal type and equipped with grates, are as equally well adapted to bituminous coal as to anthracite. Some boilers originally designed particularly for anthracite have limited combustion space, and bituminous coal cannot be burned satisfactory alone. A better procedure would be to mix one-fourth bituminous coal with three-fourths anthracite before firing.

3. Heating stoves. - Many types will burn bituminous coal alone satisfactorily, but if designed for the use of anthracite, the mixed fuel suggested above will be suitable.

4. Cooking ranges. - Because of the limited combustion space, it is usually desirable to avoid the use of bituminous coal in this equipment.

5. Fireplaces. - Bituminous coal can be used; it burns more quickly than anthracite, and the coke formed must be broken up with a poker.

B. Automatically-fired equipment:

1. Magazine-type heaters. - Because of the coking tendency of bituminous coal, the fuel will not feed by gravity as when

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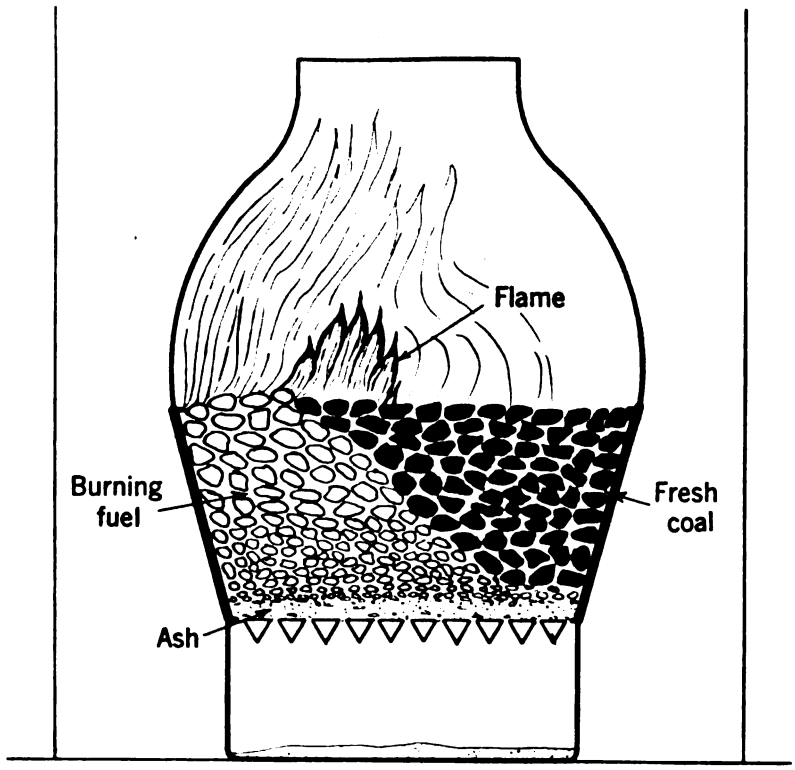

Figure 1.—Side-to-side method of firing bituminous coal.

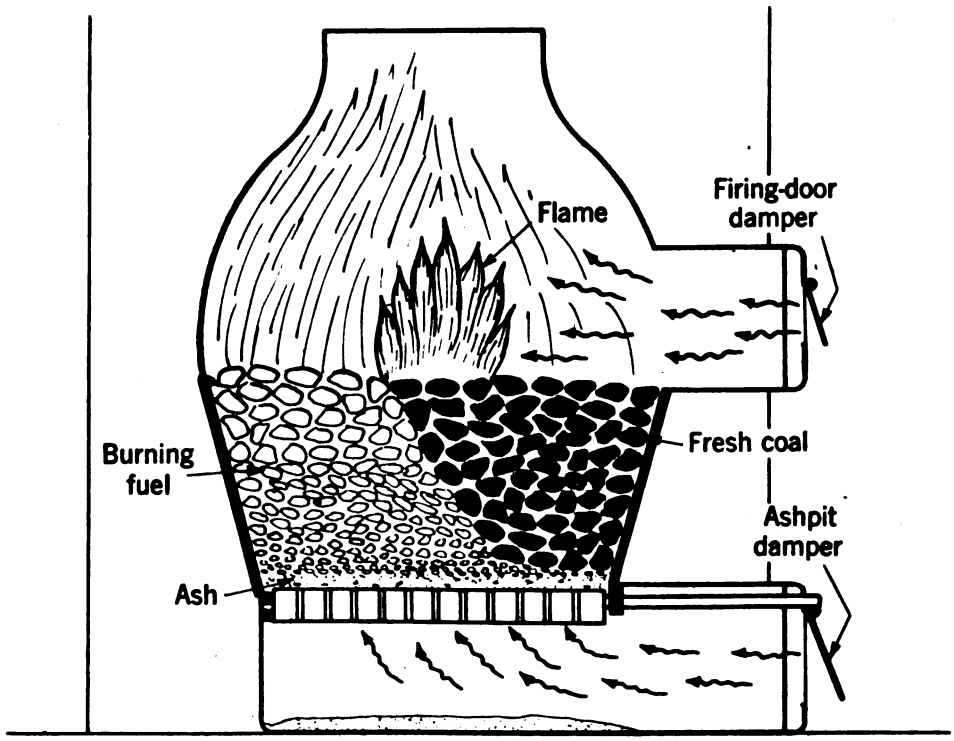

Figure 2.—Front-and-back method of firing bituminous coal.

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anthracite is being burned; thus, bituminous coal will usually be unsatisfactory in this type of unit.

2. Stokers. - Anthracite stokers are designed to burn noncaking coals; thus, bituminous coal cannot be burned in them satisfactorily.

3. Hot-water heaters. - Because excessive attention is required to maintain a fire in their small fire pots with other than noncaking fuels, bituminous coal is not recommended for these units.

4. Forced-draft blowers. - Although automatic in action when controlled by a thermostat, these devices rely upon the hand-firing of fuel. Best suited to the smaller sizes of anthracite, such as No. 1 buckwheat, they can burn successfully a mixture of one-fourth bituminous coal and three-fourths anthracite, although they do not give satisfaction on bituminous coal alone.

Substituting Bituminous Coal for Anthracite

Complete substitution of bituminous coal for anthracite is recommended only for heating equipment with large fire pots and combustion space.

Two principal methods of firing bituminous coal in domestic furnaces give best results. The "side-to-side" method is the one most commonly used; it is shown in figure 1, where the coal is piled at one side of the fire pot and does not cover the burning fuel at the other side of the furnace, leaving a hot spot exposed to serve as a point of ignition for combustible gases. When the fresh fuel is coked it should be broken with a poker, and the next firing of fuel added to the opposite side. The grates should be shaken only when considerable ash has accumulated, after which the coke in the fire pot should be pushed to one side and the firing cycle repeated.

In the second method of firing (shown in fig. 2) the burning fuel is pushed to the rear of the fire pot, and the fresh coal is piled just inside the door. By this method the combustible gases evolved from the coal are mixed with air entering through the door slots and are ignited by the hot coals at the rear of the furnace.

Control of Dampers for Bituminous Coal

Anthracite fuel beds tend to be self-damping at high fuel-bed temperatures, whereas bituminous coal burns more rapidly; thus, the ashpit damper need not

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be opened as wide with bituminous coal as with anthracite. Even so, the fire will pick up quickly, and this damper must be closed sooner to prevent overheating. Air leaks in the ashpit should be sealed with furnace cement to assure the necessary control of air into the furnace.

The slots in the firing door should be left open following a firing of bituminous coal to provide the maximum armount of air to insure burning of the combustible gases released from the coal. Later, when the fuel is coked and the gases are all driven off, these slots can be nearly closed, so that excessive cold air is not drawn into the furnace needlessly. A good rule is to leave the door slots open whenever smoke can be seen in the furnace and nearly closed at all other times.

Other dampers are adjusted similarly for bituminous coal as for anthracite.

Mixing Bituminous Coal and Anthracite

In general, the home fireman experienced in burning anthracite will obtain better results by firing a mixture of anthracite and low-volatile bituminous coal than in attempting to burn the bituminous coal alone. For mixing, anthracite and bituminous coal should be similar in size to minimize segregation. Recommended sizes of bituminous coal to be used in mixtures are:

Anthracite	Recommended bituminous-coal size, inches
Egg	4 by 2
Stove	3 by 1-1/2
Chestnut	2 by 1
Pea	1 by 1/2

The coal should be mixed before firing, preferably on the basement floor or in the opening to the coal bin. If this is not feasible, the coal can be added to the furnace in small increments, alternating the fuel to obtain mixing. In many instances it will be easiest to fire the fuel in layers as shown in figure 3, adding the necessary bituminous coal as a single layer on top of the anthracite, although it will be necessary later to break up the coke that will form. It is not recommended that any attempt be made to stir or mix the layers in the furnace.

INTRODUCTION

Like other materials in which shortages have developed because of increased demand, sufficient anthracite for home heating will not be obtainable during the season 1943-44. Recent conservative estimates show that the shortage of anthracite during the approaching heating season will be

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about 6,000,000 tons, or approximately 10 percent of the annual production. It will be difficult to increase further the amount of anthracite mined because of the shortage of manpower and equipment. No stock piles of the usual sizes of this coal are available as a reserve to supply this need. Plants manufacturing materials for war are calling for still greater quantities of fuel to produce the steam and electrical energy required in their operation, whereas the difficulty of transporting fuel oil to Eastern seaboard consumers, which has caused the conversion of oil-burning equipment to burn anthracite, also has caused the demand for this fuel to rise. Consequently, the expected maximum production of anthracite will be inadequate, and, like other materials, emergency substitutes must be provided until present conditions have improved.

Because two-thirds of all the anthracite produced in this country is used for comfort heating, much of this shortage must be absorbed by the home fireman; but so long as adequate supplies of supplementary fuels are available, there is no need for the shortage of one fuel to cause discomfort through underheating. Just as anthracite stepped in to fill the breach left when fuel oil was no longer available in its usual quantities, so also will other fuels now assist anthracite in meeting the extra demands resulting from the war.

Steps should be taken immediately to meet this new emergency. Suitable substitute fuels must be found and arrangements made to ship them into the affected areas, and fuel dealers and consumers must be apprised of the situation and told how best to adapt their facilities to it. Where the amount of such fuel handled is large, dealers may desire to install special equipment to prevent difficulties during storage. Domestic consumers must be shown how to burn the substitute fuel either alone or in combination with anthracite, and finally, the new fuel must be available to consumers having heating equipment suitable for its satisfactory use. It is the purpose of this paper to review the properties of the fuels proposed as temporary and partial substitutes for anthracite, to indicate the heating equipment most suitable for burning the substitute fuel either alone or in combination with anthracite, and to point out variations in firing and operating techniques to obtain the greatest consumer satisfaction.

FACTORS GOVERNING THE CHOICE OF A SUBSTITUTE FUEL

The fuel chosen as a substitute for anthracite must be available in large quantities, so that allotment of 6,000,000 tons or more to a new field will not interfere seriously with its normal distribution or its usual markets. It must be produced in or adjacent to the affected areas so as to minimize the freight haul and not increase the load of the already overburdened transportation system. Its use must not disturb the normal firing habits of the consumer more

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than is absolutely necessary, so that the burning of fuels other than anthracite will not cause him hardship or undue difficulty. Finally, the new fuel must be conservatively priced, so that no additional financial burden is imposed upon the already harassed home fireman.

Because of the relative simplicity of most types of equipment used for domestic heating, almost any fuel can be substituted for another in a given piece of equipment (with the exceptions noted later), although the efficiency of the process may be seriously affected. Other items, such as cleanliness and cost or the amount of attention required by the fire, although often the determining factor in choosing a fuel on the open market must be neglected during such unusual periods as the present emergency. Thus, of the large number of fuels used for domestic heating, most could be adopted as temporary substitutes for anthracite, although the decision to take such a step might be dictated by immediate necessity and not by personal choice. It is realized that the home fireman who must make such a temporary substitution will do so with the expectation of probably returning to his preferred fuel when it is again available without restriction. In the meantime he will wish to use the fuel requiring the least possible change in firing methods, that is attractive from the standpoint of cost, and that will be available in sufficient quantity to assure him of unrestricted comfort heating.

DESCRIPTION OF SUBSTITUTE FUELS

The following fuels may be used for household heating, either alone or in combination with anthracite:

1. Electricity. - Although not strictly a fuel, electricity is a convenient and clean source of heat. Its costliness, restricted availability, and the necessity for special equipment for its utilization limit its application. Not suitable generally as replacement for any appreciable amount of anthracite in home heating, electricity may nevertheless be used increasingly for heating during this emergency.

2. Gas. - Although gas, either natural or manufactured, is generally more expensive than solid fuels, it is convenient, clean, and easily adaptable to automatic control; but because of the present demand for it by manufacturing industries that require its special properties, the amount available for domestic heating is limited to existing installations. If more of it should become available, it can be adapted easily and quickly to existing equipment.

3. Wood. - Produced moderately in New England and the Middle Atlantic States, where the anthracite shortage will be felt, wood can be substituted for anthracite in only a few instances. Because of the excessive labor required

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to cut and prepare wood for use, it cannot be considered as a general substitute for anthracite, though it is easy to burn in most hand-fired space heaters. A wood fire requires instant attention and replenishment to maintain a good output of heat, but for use in open grates it is an ideal fuel, its cheery fire responding quickly to the demands of the fireman. Wood is already being used during mild weather as a satisfactory alternate fuel for anthracite on farms and in small towns and villages.

4. Coke. - On the basis of cleanliness, smokelessness, and adaptability to present equipment, coke is the most satisfactory substitute for anthracite, which it most nearly approaches in chemical composition. It is fired much like anthracite, except that better control of drafts is generally required to prevent overheating and consequent formation of clinker. However, because the demand for coke by metallurgical industries already exceeds the supply, no coke of the usual sizes can be diverted to domestic heating. In some places adjacent to coke ovens the smaller sizes of coke designated "breeze," may be available for the domestic market, but these are difficult to burn without forced-draft blowers as it is impossible to obtain the flow of air necessary for combustion with natural draft. Where such blowers are available, coke breeze can be burned, but the same care is required to prevent loss of fuel through the grates as is used with Buckwheat anthracite.

5. Oil. - Because of its unavailability, oil cannot be considered as a substitute for anthracite at present.

6. Buckwheat anthracites and culm. - No. 1 Buckwheat anthracite, produced as a "byproduct" in preparing the usual domestic fuel sizes, is burned in industrial furnaces but can be adapted to hand-fired domestic heating by mixing with larger sizes. Domestic consumers having stokers or forced-draft "Buckwheat" blowers already consume large quantities of No. 1 Buckwheat. Unfortunately, most of the available reserves of anthracite fines are in the smallest sizes - No. 3 and No. 4 Buckwheat - and are difficult to burn in any appreciable amounts in a mixture except with forced draft. By carefully mixing it at the time of firing, a moderate quantity of the No. 3 or Barley anthracite probably could be burned along with the larger domestic sizes; but in general it will cause considerable trouble and should be attempted only when no other fuel is available for use. From the standpoint of combustion efficiency, the best method of utilizing anthracite fines in domestic furnaces consists in forming them into briquets. To the extent that briquetting machinery is available, this process will be used, but the tonnage so produced will not be sufficient to satisfy the demand.

7. Bituminous coal. - Bituminous, or "soft", coal is the most reasonable substitute for anthracite. The bituminous-coal industry, already

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producing nearly 600,000,000 tons per year, is the most logical source of supply. Produced in areas adjacent to those affected by the present emergency, bituminous coal can be supplied with a minimum disturbance of existing transportation facilities; and because it costs less to mine and prepare it for market, it is less expensive than anthracite when freight charges are comparable. Although behaving unlike anthracite during the combustion process, bituminous coal can be burned successfully in many different types of equipment even though not originally designed for its use. In 1940, in the affected area - the New England and Middle Atlantic States and the District of Columbia - 1,600,000 dwelling units were heated with bituminous coal and 4,300,000 units were heated with anthracite. Since that time, conversion from fuel oil has increased the number of consumers of anthracite and possibly of bituminous coal, but the fact remains that a great many heating installations in this area already are burning bituminous coal successfully. Thus, there is reasonable consumer familiarity with bituminous coal as fuel, and dealer experience is available; therefore, the introduction of additional amounts of this fuel does not present the problems associated with the introduction of an entirely new product.

Bituminous coal mined in the eastern part of the United States is of two general types - (a) medium- and high-volatile and (b) low-volatile. A general description of their properties follows:

a. Medium- and high-volatile bituminous coal. - Coals containing 22 to 31 percent volatile matter are classified as medium-volatile and those with over 31 percent as high-volatile, but they may be grouped as a general type having similar burning characteristics; such coals are mined in Pennsylvania, Ohio, West Virginia, and Kentucky. Because of their high volatile-matter content, these coals, when heated, evolve tar and combustible gases; and when burned slowly, with long periods between firings, tar and soot are certain to be deposited in the furnace. Such coals are inherently smoke-producing, but by following simple rules of firing their tendency to form smoke can be minimized and satisfactory performance obtained. Much of this coal already is burned as domestic fuel, and the home fireman has learned that it has high heating value, ignites easily, has a moderate ash content, and is inexpensive. He has found also that it has certain disadvantages, such as the tendency to produce smoke and to deposit tar and soot in heating passages and chimneys, to break easily when handled, and to require considerably more attention than other fuels because, when heated, it becomes plastic and forms large lumps of coke. This coke is beneficial when the fire is to be held at a low heat output, as, for instance, when banking a fire overnight, but it must be broken up by hand to give a good output of heat quickly. Generally speaking, high-volatile bituminous coal can be substituted for anthracite if proper care is taken in firing it.

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b. Low-volatile bituminous coal. - This coal, also sometimes called semibituminous coal, contains less than 22 percent volatile matter on the dry, mineral-matter-free basis. It is mined extensively in Virginia, West Virginia, and Maryland, and in some parts of Pennsylvania, as in Somerset County. Because of its lower volatile-matter content, it is often referred to as "smokeless coal", although under unfavorable conditions it burns with a medium-length, moderately smoky flame. If properly fired, with suitably regulated draft, it can be burned smokelessly with very little deposition of tar and soot in the furnace, smoke pipe, or chimney. Like high-volatile bituminous coal, it is already being used extensively for home heating, its comparative freedom from smoke placing it in the premium class. Although it ignites less readily than high-volatile coal, it generally has a higher heating value because of its lower moisture and ash content. Like other bituminous coals, it is friable and therefore dusty when handled and easily broken; consequently, it usually has a larger percentage of fines when received than when shipped from the mine. It also produces coke by becoming plastic when heated, but the coke so formed can readily be broken with a poker. Most suitable in every respect, low-volatile bituminous coal is considered to be the best fuel for firing with, or in place of, anthracite when the latter is unobtainable in needed quantities. In general, this fuel will be the one most easily obtainable in the New England and Middle Atlantic States as a substitute for anthracite; its use for that purpose is strongly recommended.

Sizes of Bituminous Coal

The bituminous-coal industry has no such standards of sizing as have been accepted for anthracite because, being friable, bituminous coal is degraded in size by handling. To specify the size of bituminous coal as nut or egg or stove is somewhat indefinite, different localities and different producers using different size designations for coal of the same dimensions. Common practice is therefore to specify coal by screen sizes, the designation "4- by 2-inch" meaning coal of such a size that it will pass through a 4-inch round-hole screen and will be retained on a 2-inch round-hole screen. All bituminous coal purchased for domestic use should be specified on the basis of size by dimension.

For mixing purposes, most satisfaction will be obtained if the bituminous coal and the anthracite are nearly the same size, the tendency for segregation then being a minimum. The sizes of bituminous coal to be used for best results in mixtures are:

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Anthracite size	Recommended bituminous-coal size, inches
Egg	4 by 2
Stove	3 by 1-1/2
Chestnut	2 by 1
Pea	1 by 1/2

Bituminous coal should not be handled more than necessary, but when unavoidable dumping produces fines, the small sizes can be burned successfully by firing them on top of a bed of the larger sizes when the fire is not burning briskly. The coking action will then cause the fine particles to fuse together into large masses, which later can be broken with a poker to form pieces of coke of reasonable size, which will burn readily.

SUITABILITY OF BITUMINOUS COAL FOR USE IN HEATING EQUIPMENT DESIGNED FOR ANTHRACITE

Equipment used for burning anthracite in domestic installations falls into two general classes - hand-fired and automatically fired. Hand-fired equipment will include hot-air furnaces and steam or hot-water boilers, stoves, ranges, and fireplaces; whereas automatic equipment will consist of magazine-type heaters and all stoker-fired appliances. In general, bituminous coal can be burned successfully only in the hand-fired units.

Hand-fired Equipment

1. Hot-air furnaces. - These are best suited to the use of a substitute fuel because they have a maximum of combustion space above the top of the usual fuel bed. This greater space is valuable because it permits the combustible gas and air mixture to burn before it reaches the cool metal surfaces, thus permitting smoke-free operation. With such furnaces, low-volatile bituminous coal can be burned alone with little or no smoke or soot if the suggested firing procedures are followed. In the New England and Middle Atlantic States, 18.6 percent of all heating units are this type.

2. Steam and hot-water boilers. - Such equipment is most common in the affected area, 41.9 percent of the dwelling units in New England and 50.8 percent in the Middle Atlantic States being equipped with steam or hot-water central heating plants. Many of them are the universal type, so designed that they can be adapted to oil, gas, or coal. When equipped with coal grates, they are as equally well adapted to bituminous coal as to anthracite and will be completely satisfactory with low-volatile bituminous coal; a great many such heaters already are burning bituminous coal satisfactorily at minimum cost. The home fireman burning bituminous coal for the first time will experience little trouble from such equipment. Probably he will prefer to burn

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bituminous coal separately during the colder winter weather rather than trouble to mix fuels. There is a greater tendency for soot to deposit in the smaller and cooler passages of this equipment than there is with hot-air furnaces; therefore, it is more necessary to employ correct firing procedures with steam and hot-water boilers when burning bituminous coal.

Some boilers have been specially designed to burn anthracite and have limited combustion space, chiefly because of economic considerations and for minimum space requirements. With anthracite, decreased volume over the fuel bed is permissible, but with bituminous coal the tendency to smoke or produce soot will be aggravated in such units, as with undersize equipment. Therefore, when this type of boiler is used it will be necessary to premix the fuels before firing to obtain continuous, satisfactory operation. The home fireman will be the best judge of his own equipment. If he suspects that insufficient furnace volume is causing smoke when firing bituminous coal alone or in layers, he can largely eliminate the difficulty by premixing the coals, as noted later. If smoke still persists, it indicates either that the fire door slots could be opened farther or that the dampers should be adjusted to give a lower rate of burning. In any case, with such equipment, more care must be taken in firing than when the combustion space is greater.

3. Heating stoves. - According to the 1940 census figures, 40.4 percent of the dwelling units in New England and 26.8 percent of those in the Middle Atlantic States are not equipped with central heating plants but are heated by stoves. In these stoves, low-volatile bituminous coal can be substituted in part for anthracite without undue difficulty. Recently, stoves have been developed that can burn even high-volatile bituminous coal smokelessly by utilizing principles known for years to fuel engineers. Where these or similar stoves are available, anthracite can be completely replaced without trouble, even to the stoves' ability to maintain a fire overnight.

With old-fashioned "hard-coal" stoves it is recommended that the anthracite be mixed with the maximum amount of bituminous coal for operation during the day, and that the fire be banked overnight with anthracite alone. Because the characteristics of these stoves vary greatly, the most effective method of utilizing low-volatile bituminous coal can be determined best by trial.

4. Cooking ranges. - Anthracite is used in many ranges not only for cooking but as a source of heat for the kitchen or nearby rooms. Most ranges have very limited combustion space, and the tendency of even low-volatile bituminous coal to produce smoke and soot will be intensified. By firing a mixture of the two fuels, the quantity of smoke will be a minimum, and the greatest possible satisfaction will be obtained. When bituminous

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coal is used in such equipment, it will be necessary to remove the soot periodically to maintain satisfactory performance. The minimum possible amount of substitution is recommended for this type of equipment.

5. Fireplaces. - Many fireplaces are the only source of heat in a room. Others serve as auxiliary heating devices, their bright and genial fire being not the least of their attraction. Although anthracite yields a bed of cheerfully glowing coals, bituminous coal is also a satisfactory fuel, the principal difficulty in burning it in open grates being its tendency to form coke. Once this coke has been produced and is broken with a poker, the fire behaves like an anthracite fire. Bituminous coal has certain advantages over anthracite when burned in fireplaces, the principal one being that heat is obtained more rapidly. Thus, when a cold room must be heated quickly and a fire must be freshly kindled, bituminous coal will burn at two to three times the rate of anthracite and consequently will heat the room more quickly. On the other hand, anthracite will burn more slowly, but the total heat produced will be the same in either case. It is therefore recommended that when a fire is wanted during mild weather or for banking purposes, anthracite be used alone, but when heat is desired quickly, low-volatile bituminous coal is more suitable. Like other burning equipment, fireplaces will vary somewhat, and the home fireman can best determine how to get most satisfaction by actual trial. Burning the fuels separately or in layers is suggested as the most satisfactory course.

Automatically-fired Equipment

The principle deterrent to the use of bituminous coal in automatically-fired heating equipment is its tendency to form massive lumps of coke, which burn more slowly than does coal because less surface is exposed per unit of weight. Also, their shape and size interfere with the normal movement of the fuel bed, so that some sort of agitation generally is required. In hand-fired equipment this agitation is supplied by the fireman with his poker; mechanically driven pokers are used in some domestic stokers designed for bituminous coal, but such devices are not included with anthracite stokers, where caking never occurs. As a rule, bituminous coal should not be used in automatic domestic burning equipment designed for anthracite and feeding fuel by gravity or mechanical methods.

1. Magazine-type heaters. - In an attempt to reduce the attention required to fire ordinary types of furnaces, the magazine heater was devised. If the grates of the furnace are set at the proper angle and a hopper of coal is installed at the upper end, the coal will slide down and maintain itself on the grates at some given thickness fixed by adjustment of the hopper gate; but if some coking coal is burned in place of anthracite or sized coke, a

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a sheet of coke will be formed over the grate, which will interfere with the further feeding of coal. Also, coal coked in the hopper by conduction of heat from the fuel bed will form a plug at the hopper exit, so that no more fuel can be fed. For this type of equipment, care must be taken to choose a fuel that is "free-burning"; that is, it must not cake when heated. It is therefore recommended that no bituminous coal be burned in such equipment.

Certain types of anthracite-burning magazine heaters feed the coal through a vertical cylinder. Any tendency for coke to form from the fuel in this cylinder will interfere with the free movement of the coal, and bituminous coal should not be used. An exception is the type of magazine stove designed to burn bituminous coal where coke formation is not a deterrant to successful operation. If trials with bituminous coal are made, it should be well mixed with anthracite before being placed in the hopper, and generally it should not exceed 25 percent of the mixture. The estimated 120,000 magazine feed boilers in the affected territory do not account for a large tonnage of anthracite.

2. Stokers. - Anthracite underfeed stokers, although fundamentally similar to those for bituminous coal, have specially designed retorts for burning noncaking coals. The principal difference between the two types is that anthracite is burned in a compact mound in the retort, the spent ashes usually overflowing the retort to drop into a pit or onto a conveyor for removal; whereas in bituminous coal stokers coke is formed in the retort and is burned largely outside the retort proper, and the ashes are removed as clinkers. Therefore, if a caking bituminous coal is burned in an anthracite stoker, loss of coke to the ashpit will be excessive, and it may even be impossible to maintain a fire. By installing a solid horizontal refractory lining between the retort and the furnace wall to form a surface on which the unburned coke could rest, bituminous coal could be burned more satisfactorily; but it is generally too difficult, except for trained furnace mechanics, to build such "dead plates" in most installations, and on some ash-removal stokers it would be virtually impossible. Because the estimated 115,000 domestic anthracite stokers burn only about 1-1/4 million tons of anthracite annually, or about 3 percent of the total domestic demand, it is not considered imperative that they be converted to utilize a substitute fuel.

3. Hot-water heaters. - Although only a few hot-water heaters are completely automatic, employing a miniature edition of the larger anthracite stoker, the remainder are generally operated with controls actuated by water temperature, so that they require no attention other than fueling and removing ashes once a day. Anthracite is an ideal fuel for these "bucket-a-day" heaters because it responds adequately to change in the draft dampers, whereas a coking coal would require additional attention

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to maintain a satisfactory fire; therefore, substitution of bituminous coal in these units is not recommended. An estimated 4,000,000 tons of anthracite is burned annually in these heaters.

4. Forced-draft blowers. - Forced-draft blowers, used in burning the smaller sizes of anthracite, such as No. 1 Buckwheat, when controlled by a thermostat can be classed as automatic, although the fuel is actually hand-fired on a grate. These blowers can be used with bituminous coal, except that the coke formed must be broken up by the fireman to permit adequate rates of burning and efficient operation. For coking coals, the blower may lose a large portion of its effectiveness; therefore, bituminous coal will be most satisfactory as a substitute fuel in such equipment when it is premixed with the anthracite, this mixture having a minimum tendency to form coke.

UTILIZATION OF SUBSTITUTE FUEL

Low-volatile bituminous coal can be used as a partial substitute of anthracite by burning the two fuels either individually or as a mixture. If burned mixed, the fuels can be premixed in the cellar or fired in alternate small additions to the heating equipment. In any case, the two fuels should be delivered into a vertically partitioned bin, so that the coals will not be mixed until wanted. If mixed in the dealer's yard or in the delivery truck, partial segregation may occur on dumping into the coal bin, with the result that the home fireman will be unable to control the proportions for any given firing. For greatest assurance of success he should be able to determine the quantities of each fuel to be put into the fire pot, because then, after only limited experience, he would be better able to adapt his proportioning technique to the demands of the weather and the eccentricities of his equipment.

The quantity of substitute fuel required probably will vary with the location, depending somewhat upon shipping requirements. Because it will be essentially impossible to operate some types of automatic equipment with any fuel but anthracite, for which they were particularly designed, it will be necessary to increase the proportion of bituminous coal to other consumers; that is, many consumers will only be able to buy, say, three-fourths of their usual annual supply of anthracite, so that this fuel must be extended 25 percent, preferably with low-volatile bituminous coal. For the average home that usually burns say, 12 tons of anthracite per year, this means that at least 3 tons of bituminous coal must be substituted for an equal quantity of anthracite.

To keep the coals separated, it will be necessary only to partition the bin so that either coal can be reached from the opening. Anthracite in domestic sizes weighs 52 to 56 pounds per cubic foot, whereas bituminous coal of similar size weighs 47 to 52 pounds per cubic foot. Anthracite is approximately 9 percent heavier than bituminous coal, consequently allowance should be made in partitioning small bins for the greater volume required per ton

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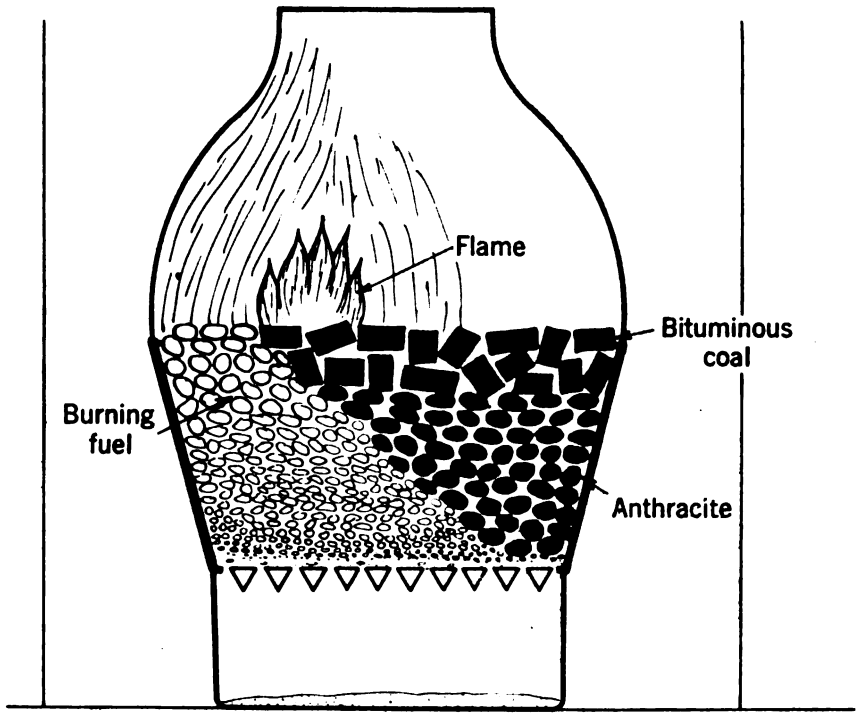

Figure 3.—Suggested method of firing anthracite and bituminous coal without premixing.

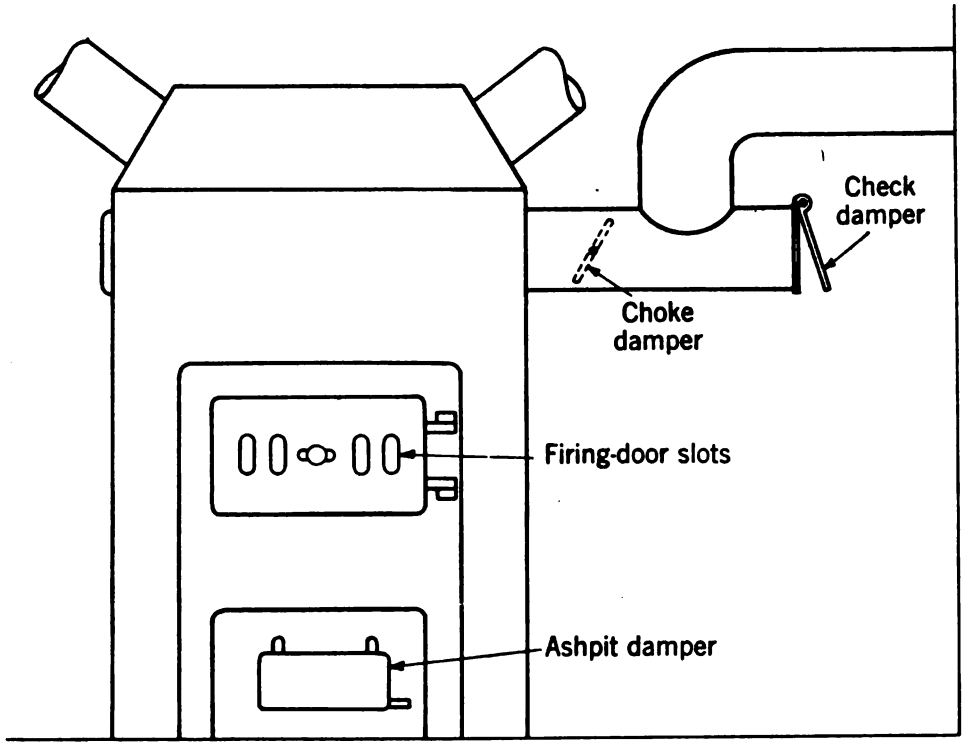

Figure 4.—Typical arrangement of dampers for a warm-air furnace.

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for bituminous coal. In most residences, bin capacity usually is more than adequate, and it will not be necessary to compensate for this difference.

Burning Two Fuels Simultaneously as a Mixture

Burning a mixture of anthracite and low-volatile bituminous coal has certain advantages over burning these coals separately. A mixture of three-fourths anthracite and one-fourth low-volatile bituminous coal will have a mean volatile content of only 7 to 12 percent and should be smoke-free under most conditions. Because bituminous coal will burn more rapidly, the fire will tend to be more lively at first, but later it will burn in a manner typical of anthracite. The tendency of bituminous coal to form coke, which must be broken up to permit continued high rates of burning, will be minimized because the hot plastic coal lumps will be separated by pieces of anthracite so that they cannot flow together to form a single coherent mass. As the ash content of the bituminous coal probably will be low, only moderate clinkering should be encountered, and the behavior of the ash should be improved from the standpoint of dustlessness.

In general, although it is more troublesome to mix coals before firing, mixed coal requires less attention than bituminous coal burned alone, and the home fireman probably will find that the labor of mixing will be more than compensated by satisfactory performance.

Burning Two Fuels Simultaneously in Separate Layers

The labor required to premix anthracite and bituminous coal before firing will deter many from adopting this method. An easier method of firing would be to use three scoops of anthracite followed by one of bituminous coal. The bituminous coal should be added last for two reasons - first, it will be heated gradually by the slowly igniting anthracite, evolving its volatile matter slowly and therefore smokelessly; and second, the coke formed by the bituminous coal, being on the surface of the fuel bed, can readily be broken up with a poker to assist in controlling the rate of heat output. This method of firing anthracite and bituminous coal in combination is shown in figure 3. Where a high output of heat is required suddenly, such as on a cold morning following a period of mild weather, a single scoop of bituminous coal should be fired and the dampers adjusted for a high rate of burning. When the required amount of heat is obtained or the coal is largely consumed, anthracite followed by bituminous coal should be fired as described above.

It is not recommended that the layers of anthracite and bituminous coal be mixed in the fire pot by stirring with a poker because of the difficulty of obtaining a good mixture and because ash may be lifted into the fuel bed and cause excessive clinkering.

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Burning Two Fuels Separately

Some home firemen will prefer to burn the two fuels unmixed, with the advantage that normal firing habits are not disrupted during most of the heating season. A disadvantage is that an entirely new firing procedure must be followed while the substitute fuel is being burned. In such instances it would be preferable to burn anthracite exclusively during fall and spring, when relatively little is needed, and the fire may require frequent banking. During the colder winter months bituminous coal can be burned advantageously because of its higher rate of "pick up". One drawback to this scheme is that small fire pots are unsuited to bituminous coal and even low-volatile coal may smoke. For those using this method, the suggestions made for firing bituminous coal must be followed carefully to obtain satisfactory results.

Because only a minor amount of the required heat must be produced from bituminous coal (25 percent has already been suggested as the average) burning this fuel alone during the coldest weather will cause the least disturbance to established firing techniques. In Portland, Maine, for example, 18.3 percent of the total heating load for the year occurs in January and 16.0 percent in February; if bituminous coal is burned exclusively during this period, the entire quantity will be consumed within 6 weeks.

It is believed that most home firemen will prefer to burn the substitute fuel gradually during the entire heating season, becoming acquainted with its performance in mild weather so that they may be better prepared when cold weather arrives; but those already experienced in firing bituminous coal, and who have satisfactory equipment, will probably prefer this last method because it entails the least labor.

GENERAL FIRING INSTRUCTIONS FOR BITUMINOUS COAL

Fuels liberate heat because they oxidize, that is, because they combine with the oxygen in the air. This rate of oxidation, and therefore of heat output, is negligible when temperatures are low; but above a certain temperature oxidation proceeds spontaneously. This certain temperature varies with the fuel substance and the surroundings and may be difficult to fix with a complex substance such as coal, although it is generally well defined for gases; it may be called the "ignition temperature". Its importance lies in the fact that a combustible gas, although mixed with sufficient air, must be raised to the ignition temperature before combustion takes place with production of heat. Therefore, combustible gases distilled from a bed of gradually heating coal will escape unburned, unless a source of high temperature is available to cause their ignition.

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This situation is exactly analogous to that of a gas burner under a pan of water. When the gas is turned on it mixes with air and impinges upon the bottom of the pan, but heating will not take place because the gas-air mixture has not itself been heated to the point where combustion, or oxidation, can furnish additional heat. Applying a burning match furnishes the necessary heat energy to ignite the flame, which then supplies heat to the pan of water as well as that required to maintain itself alight. Similarly, in starting a fire with coal, some kindling must first be burned to raise the temperature of the coal to the point where sufficient heat is being evolved to maintain the fire and also to maintain a source of heat to ignite combustible gases distilled from the coal.

The importance of this ignition requirement is obvious when it is realized that a quarter to a half of the heat supplied from bituminous coal is furnished by the combustion of the volatile gases evolved when the coal is heated. Unless these gases are ignited and burned, a large potential source of heat is being wasted up the chimney. Therefore, the first consideration in burning bituminous coal is to add only such a quantity of fuel at one time to the furnace or stove as can be placed on the old fuel bed and leave a glowing spot of coals to act as a "match" to ignite the gases distilled from the fresh charge. After an hour or two, when this charge is completely coked and all the volatile gases are driven off, additional coal may be added, again leaving a spot of glowing coals to insure ignition. In very cold weather it may be necessary to make several such firings before a large enough mass of coke accumulates in the furnace to keep the house warm overnight. By doing this in the late afternoon or early evening, as the outside temperature falls, the heat from the burning volatile matter maintains a comfortable temperature indoors during the evening and leaves a good bed of coke for banking.

Two principal methods of firing bituminous coal are used in domestic furnaces. The more common is the "side-to-side" method, shown in figure 1, in which the fresh fuel is heaped at one side of the fire box by spilling the shovel at one furnace wall. Only enough coal is added so that burning coal or coke form the previous firing is still exposed on the other side to act as an igniting spot. When the fresh fuel is completely coked, it is broken up with a poker, and the next firing is made on the opposite side. Only when enough ash has accumulated to require removal should the grates be shaken, after which the coke still in the fire pot should be pushed to one side and the firing cycle repeated.

The other method consists, for each firing, of pushing all the hot coals to the rear of the fire pot and piling the fresh coal just inside the door; this method was illustrated in figure 2. An advantage of this scheme is that the combustible gases evolved from the new coal charge are mixed with air entering through the door slots, giving a better air-gas mixture, which passes directly over the hot coals at the rear to become ignited. The principal disadvantage is that considerable movement of the burning coal or coke is required and therefore clinker may

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be formed by raking ash up into the high-temperature burning zone. Many home firemen employing this method provide themselves with a stout metal-handled hoe with which to move the burning fuel to the rear of the fire pot, although it can be done, with more difficulty, with a shovel. The University of Illinois has suggested that a suitable tool for moving hot coals in the furnace, and one that will reach any portion of the grate, can be made by bending the end of an ordinary poker 13 inches from the tip so that it forms an oblique angle of 30°. Again, the most important thing to be observed is that the fuel bed must at all times have a brightly burning spot, no matter how small, so that combustible gases will not pass off unburned or accumulate in the furnace to give an explosive "puff" when ignition occurs. Either of these methods gives more efficient and satisfactory burning than haphazard firing of coal.

With very low-volatile fuel, such as anthracite, similar firing methods will prevent furnace "puffs" and bring about more certain combustion of the carbon monoxide produced in the fuel bed, particularly shortly after firing; but no tar or soot will be deposited, nor will smoke be produced, if the operator fails to follow proper firing procedures. When medium- or high-volatile bituminous coal is used it is imperative that such practices be followed to obtain even reasonable satisfaction; and with low-volatile bituminous coal the employment of such methods results in virtually smokeless operation, relatively little or no soot or tar depositions in the equipment, and most economical production of heat. With the latter fuel, the firing charges can be larger than with high-volatile coal, and therefore less frequent, and yet be satisfactory.

Control of Rate of Burning

Controlling a bituminous-coal fire is like controlling an anthracite fire, in that passing more air through the fuel bed results in a greater production of heat. Therefore, the basic function of the draft dampers in a furnace burning bituminous coal is the same as when anthracite is the fuel, but there is a marked difference in the responsiveness of the fire, anthracite fuel beds tending to be self-damping at high fuel-bed temperatures, whereas bituminous coal burns more briskly at the higher temperatures. Figure 4 shows a typical arrangement of the dampers on a warm-air furnace.

1. Ashpit damper. - This damper, usually a part of the ashpit door but occasionally built into a side of the ashpit, admits air to the space below the grates, from whence the air passes through the grates into the fuel bed, oxidizing the coal and thereby producing heat. With bituminous coal this damper usually need not be opened wide to insure maximum possible rate of burning or "pick-up" of the fire. Long operation with the ashpit damper open almost invariably will permit the liberation of

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too much heat, so that this damper should be closed before the house reaches a comfortable temperature to avoid overheating. The rate of "pick-up" for bituminous coal is much higher than for anthracite, because of the rapid evolution and burning of the volatile constituents; that is, the coal is "livelier". Engineers say it is more reactive, which is equivalent to stating that it combines more readily with oxygen. Therefore, when burning bituminous coal it should be remembered that the damper need not be opened so far for rapid "pick-up", or, if fully opened, should be closed sooner than when anthracite is burned. This particular point should be impressed upon new users of bituminous coal; the anthracite fireman, who is accustomed to leaving the ashpit damper open for a long time, is likely to cause damage to his furnace from overheating if he follows similar practices with bituminous coal; also, he will be wasteful of fuel. If the ashpit of the heater leaks badly, closing the ashpit damper may not prevent some air from flowing through the fuel bed and thus maintaining too vigorous a fire. Such leaks should be sealed with furnace cement, so that the ashpit damper will have full control over the flow of air into the furnace.

2. Check damper. - Usually, on the top of hot-water or steam boilers or in the smoke pipe, as in hot-air furnaces, is the check damper to reduce the amount of air passing through the furnace. This it does by allowing air to pass directly into the smoke pipe, effectively "shorting" the furnace so that the chimney provides little or no draft on the furnace, and consequently little air is drawn through the fuel bed. Actually, because the furnace is essentially a short chimney, some air will flow, but normally this can be controlled by closing the draft damper in the ashpit. Little difference in the operation of the check damper will be observed with bituminous coal as compared to anthracite other than as mentioned for the ashpit damper, because of the high rate of burning of bituminous coal; but it will be necessary to open this check damper much sooner after firing bituminous coal to prevent overheating. With most furnaces, both ashpit and check dampers operate from a single control, and the check damper often cannot be opened until the ashpit damper is closed.

3. Choke damper. - This damper, also called the "turn" damper, is usually adjusted only seasonally, being opened wider during midwinter to permit a higher rate of burning. Choke dampers are not found in all installations. It consists of a simple butterfly valve between the furnace and the check damper and acts by increasing resistance to flow of gases through the smoke pipe, thereby decreasing the quantity of gases passing through the furnace. It must be adjusted carefully to prevent closing it too far, in which case the furnace will discharge the products

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of combustion into the house. With bituminous coal this maladjustment is less likely to occur than with anthracite because the accompanying smoke is irritating and calls attention to itself, whereas with anthracite the flue gas, being nearly odorless, may not be perceived. Because under some conditions flue gas may contain reasonably large amounts of the deadly gas carbon monoxide, care must always be taken not to close the choke damper to the point where gas can escape from the furnace into the house. If in doubt, it is better to leave the choke damper open and to control the minimum rate of burning by opening the check damper, closing the ashpit damper, and sealing any leaks in the ashpit.

4. Firing-door damper. - As has been stated, air must be mixed with the combustible gases evolved by the fuel bed to permit their combustion or oxidation. Sometimes this air is part of that supplied to the grates and which has passed through the fuel bed without combining with the fuel, perhaps because the fuel bed is thin in spots or is open or cracked. A more certain way of supplying this air is through the firing door by opening the slots or the small "hot blast" door. Generally, to insure that sufficient air to ignite evolved gases is present immediately after firing a fresh charge of any bituminous coal, the firing-door slots should be left open. Later, when the fuel is coked and the volatile matter has been driven off, these slots can be closed so that excessive amounts of cool air are not drawn through the furnace to carry off useful heat. A good rule for adjustment of door slots is that they should be wide open whenever smoke can be seen in the fire pot and nearly closed at all other times, except that whenever a slight "puff" occurs on opening the furnace door the slots should be left open. This indicates that not enough air is entering through or around the door to burn all the gas in the combustion chamber. Whereas in general anthracite can be burned successfully with the firing-door slots nearly closed, with bituminous coal they should be open most of the time.

Formation of Clinker

With the better grades of anthracite, the ash, although usually greater in quantity than with bituminous coal, does not ordinarily form dense clinkers, because it consists chiefly of refractory substances. In bituminous coals, however, the ash may contain enough fluxing constituents to cause the ash to melt at ordinary fuel-bed temperatures. Such an ash will tend to produce clinker, which will be objectionable to the extent that it may cause damage to the grates or interfere with burning by restricting the flow of air through the fuel bed, and is difficult to remove without seriously disturbing the fire. It does not always follow that the most refractory ash is desirable or that a coal having an easily fusible

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ash cannot be burned satisfactorily; an ash that does not fuse but remains dusty is a nuisance to handle and may dirty the whole house. The optimum condition is the formation of porous, easily friable clinker that does not interfere with the flow of air but that can be removed readily by shaking the grates. Such clinkers represent minimum dustiness and the least possible volume, the same quantity of ash when light and fluffy occupying as much as three times the space required by good clinkers. In general when bituminous coal is fired in the smaller fire pots used for anthracite, somewhat more clinkering can be expected than in larger furnaces.

Clinkering can be controlled largely by following certain simple rules:

1. Do not allow the fire to burn at a higher rate, and consequently a higher temperature, than is necessary.

2. Do not check the fire abruptly after burning at a high rate unless absolutely necessary; sudden interruption of the flow of air will permit the temperature of the ash in the fuel bed to increase excessively.

3. Do not allow ashes to accumulate on the grates more than necessary to protect them from fuel-bed temperatures, except in mild weather when operating at very low rates of burning.

4. Do not stir the fuel bed with the poker. Raising the ash from the grates to the high-temperature burning zone is certain to promote fusion and consequent formation of clinker. Note that "stirring" is differentiated from "poking". In the former the bed is agitated strongly, whereas the latter signifies gentle prodding of the fuel bed to break the coke.

Removal of Soot

Although low-volatile bituminous coal properly burned produces no smoke or soot, yet in equipment not designed for its utilization some soot may accumulate on heating surfaces or in the smoke pipe or chimney. With medium- and high-volatile bituminous coals, soot formation is almost inevitable. Where soot cannot be removed easily by brushing, or where that method is undesirable, soot can be removed by burning. Following is the recommended procedure:

1. Prepare a bed of hot coals by operating the heater at a moderate or high rate, breaking up all coke to give a reasonably level fire.

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2. Close ashpit damper and slots in firing door.

3. Scatter common rock salt over the red-hot fuel, using one cupful for a small heater or two cupfuls for a large furnace.

4. Quickly close the firing door and open the check damper, allowing the salt to act for 10 to 20 minutes.

5. Close the check damper and open the ashpit damper, so that the fire may burn briskly. Possibly shake the grates lightly to permit a hotter fire.

6. Open the firing-door slots and possibly the door itself, so that a good supply of air may enter.

7. If the soot in the smoke pipe does not ignite, put a piece of newspaper into the furnace, so that flames will reach the soot.

Any appreciable accumulation of soot will burn if these instructions are followed, the effectiveness of common salt being nearly as great as that of the proprietary compounds on the market. Mixing a small quantity of red lead or copper or zinc filings with the salt will increase its effectiveness.

It is better to remove soot at regular intervals than to allow it to accumulate until it interferes with the draft. The intervals between cleanings will depend largely on the type of heater, the volatile content of the coal and the manner in which it is fired, and the season; soot accumulates more rapidly in the spring and fall when burning rates are low.

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